Abstract

Recent developments in the area of microfabrication technologies, has enabled the fabrication of many radio frequency/microwave components with better performance and lower cost than possible with semiconductor based fabrication technology. Many of these microfabricated RF components such as switches and phase shifters, popularly known as RF MEMS, are aimed at reducing the insertion loss and improving other performance parameters such as linearity. For these devices size miniaturization is not necessarily important, as in practical subsystems, these components are integrated with RF front-ends on a laminate. This thesis deals with concepts of a low cost passive phase shifter fabricated in-situ on a microwave laminate. The operation of this Mesoscale Electrostatically actuated Phase shifter on microwave Laminate (MEPL) is similar to that of a micromachined distributed MEMS transmission line (DMTL) phase shifter.

In spite of advantages of low losses, wide bandwidth, low DC power consumption and high linearity over semiconductor/MMIC technology, microfabricated phase shifters are often not used in field because of issues related to fabrication reliability, packaging and integration. On the other hand, the proposed MEPL will have all the advantages of conventional MEMS phase shifters with additional benefit of lower cost. Furthermore, these are integrable to form a monolithic phased array.

A MEPL phase shifter of 50-bridges periodically distributed on the co-planar waveguide (CPW) transmission line is demonstrated in this thesis. MEMS air bridges are electrostatically actuated to vary the capacitance of the transmission line, which changes the phase velocity of the propagation RF signal, consequently phase at the output port. The realized MEPL is characterized for electromagnetic as well as electromechanical performance. The electromechanical characterization of this device is performed using a Laser Doppler Vibrometer (LDV). The measured data showed good agreement with the analytical data..

Major application of a phase shifter is in a phased array antenna system. MEPL is particularly suited for a monolithic phase array antenna. The proposed monolithic phased array antenna system fabrication approach utilizes extremely simple and economical modern printed circuit board technology to pattern the conventional microwave laminate and copper foil. A complete monolithic phased array antenna system is fabricated on a microwave laminate using an embedded phase shifter operating with electrostatic principles. Other components such as DC block and bias tee are integrated into the CPW-microstrip transitions to optimize the space and performance. Integrated phased array antenna is fabricated and tested to demonstrate the beam steering capability. Measured S11 is better than -15dB at the operating frequency of 9.8GHz. The beam steering capability is shown as proof of concept by showing the beam scan angle of 10deg with bias voltage of 125V.

The mesoscale phase shifter demonstrated in this thesis has several advantages compared to micromachined phase shifters. The proposed fabrication approach does not use metal deposition/patterning process, which removes the need of high cost clean room and sophisticated films deposition equipments. Secondly, as there are no thin films used, stiction is not expected on phase shifters fabricated with this approach. Since this approach uses thicker metal films, the power handling capability is expected to be significantly higher than micromachined phase shifters. Since conventional phased array antenna system components are fabricated on a microwave laminate, micro machined phase shifters realized on semiconductor substrates are required to be packaged separately before integrating with such phased array circuits. Packaging of the micro-machined RF-MEMS/MEMS devices is still a major issue and contributes to a substantial part of the total cost. Unlike micromachined phase shifters which are required to be packaged and then embedded in phased array applications, device presented in this thesis is packaged *in-situ*. Compared to similar monolithic phased array antenna reported on silicon substrate which are limited by wafer size, these arrays can be easily extended for larger arrays on microwave laminate as these are available in large size.

To summarize, the proposed fabrication approach for phase shifters overcomes many limitations of micromachined components for microwave applications while retaining most of their advantages compared to other existing approaches based on ferrites or semiconductor technologies.